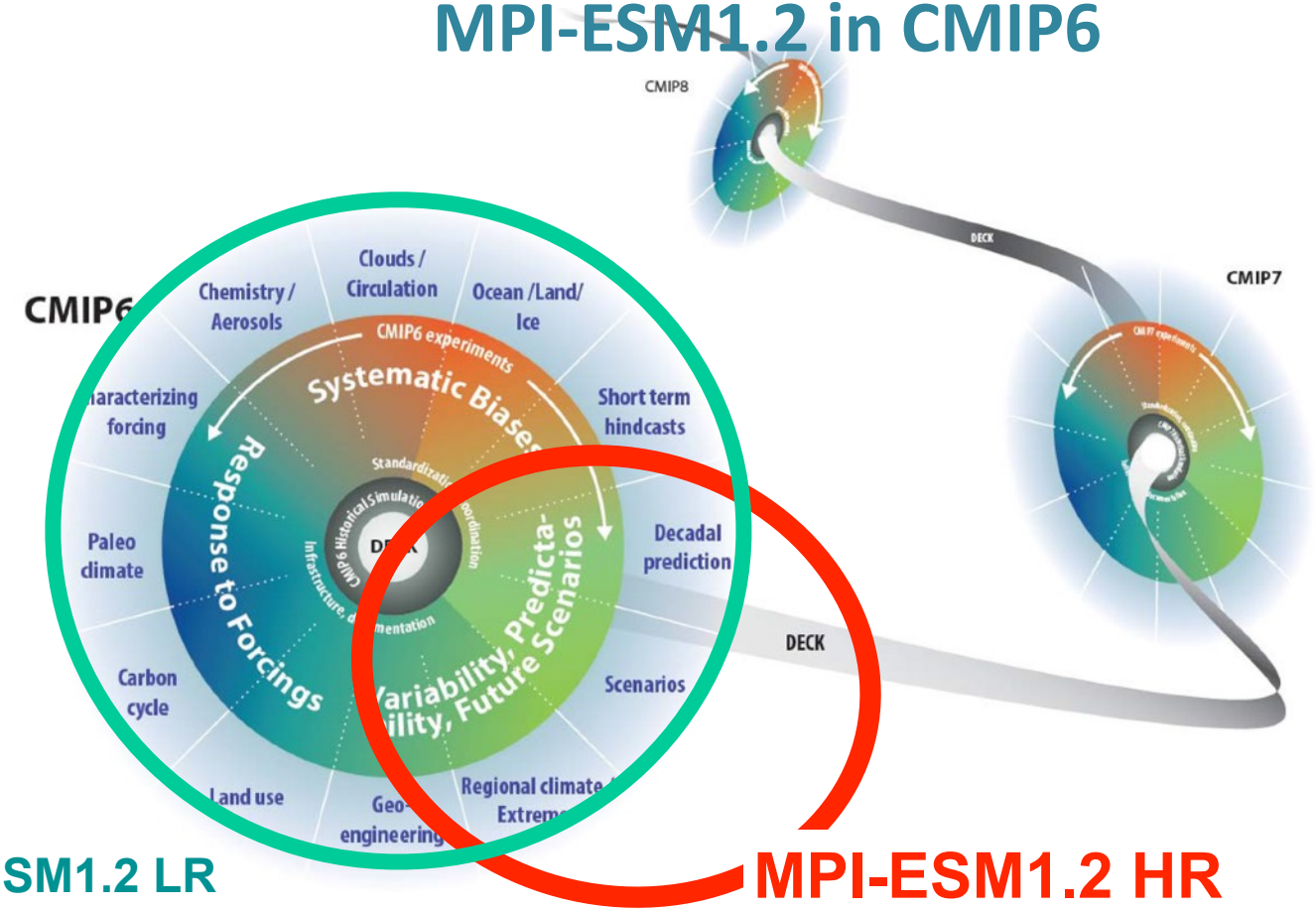
MPI-ESM in CMIP6

Johann Jungclaus, Karl-Hermann Wieners, Matthias Bittner, Kameswarro Modali, Wolfgang Mueller, Holger Pohlmann, Helmuth Haak
et al.,

MPI-ESM1.2 in CMIP6



MPI-ESM1.2 LR

MPI-ESM1.2 HR

MPI-ESM1.2

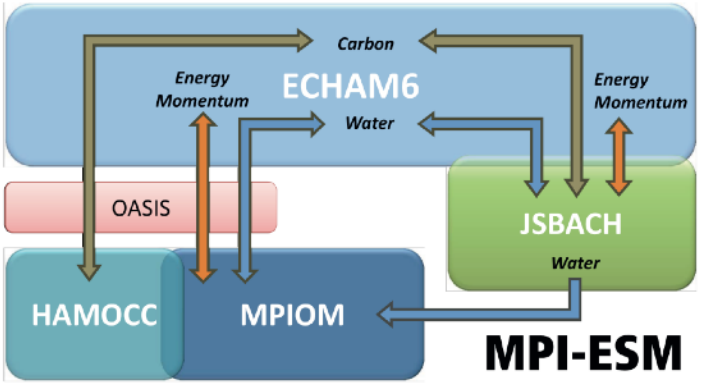
Documentation:

Mueller et al., JAMES, 2018

Mauritsen et al., JAMES, 2019

HighResMIP:

Gutjahr et al., GMD, 2019



	CMIP6		HighResMIP		
	CR	**LR**	**HR**	**XR**	**ER**
atm.	T31L31	T63L47	T127/L95	T255/L95	T127/L95
ocn.	GR3.0/L40	GR1.5/L40	TP04/L40	TP04/L40	TP6m/L40

MPI-ESM1.2 in CMIP6

	MPI-ESM1.2-LR	MPI-ESM1.2-HR	MPI-ESM1.2-XR*
Atmosphere	ECHAM6.3		
	T63 (1.9° x 1.9°) 47 vertical levels to 0.01 hPa	T127 (1.0° x 1.0°) 95 vertical levels to 0.01 hPa	T255 (0.5° x 0.5°) 95 vertical levels to 0.01 hPa
Ocean	MPIOM1.63		
	GR1.5 (1.5° x 1.5°) 40 levels	TP04 (0.4° x 0.4°) 40 levels	
Additional components	**Land:** JSBACH3.20 including dynamic vegetation + Carbon- and Nitrogencycle **Ocean-Biogeochemistry:** HAMOCC	**Land:** JSBACH3.20 without dynamic vegetation, Carbon- and Nitrogencycle **Ocean-Biogeochemistry:** HAMOCC	

MPI-ESM-1.2-HR DICAD core simulations

MPI-ESM1-2-HR

[----------] 100% - **piControl(MiKlip)** - 500 years started/finished at 24 Jul 2017 / 5 Sep 2017
[----------] 100% - **1ptCO2(MiKlip)** - 150 years started/finished at 11 Oct 2017 / 22 Oct 2017
[----------] 100% - **abrupt4xCO2(MiKlip)** - 150 years started/finished at 19 Sep 2017 / 5 Nov 2017
[----------] 100% - **historical-Real1(MiKlip)** - 165 years started/finished at 2 Aug 2017 / 21 Aug 2017
[----------] 100% - **historical-Real2(MiKlip)** - 165 years started/finished at 3 Aug 2017 / 20 Aug 2017
[----------] 100% - **historical-Real3(MiKlip)** - 165 years started/finished at 2 Aug 2017 / 12 Sep 2017
[----------] 100% - **historical-Real4(MiKlip)** - 165 years started/finished at 21 Aug 2017 / 6 Sep 2017
[----------] 100% - **historical-Real5(MiKlip)** - 165 years started/finished at 21 Aug 2017 / 11 Sep 2017

[----------] 100% - **amip-Real1** - finished Jan 2019
[----------] 100% - **amip-Real2** - finished October 2019
[----------] 100% - **amip-Real3** - finished October 2019
[----------] 100% - **piControl** - 500 years started/finished by Dec 2018
[----------] 100% - **1ptCO2** - started, finished Feb 2019
[----------] 100% - **abrupt4xCO2** - finished Feb 2019
[----------] 100% - **historical-Real1** - finished Jan 2019
[----------] 100% - **historical-Real2** - finished Jan 2019
[----------] 100% - **historical-Real3** - finished Jan 2019
[----------] 100% - **historical-Real4** - finished Jan 2019
[----------] 100% - **historical-Real5** - finished Jan 2019
[----------] 100% - **historical-Real6** - finished Jan 2019
[----------] 100% - **historical-Real7** - finished Jan 2019
[----------] 100% - **historical-Real8** - finished Jan 2019
[----------] 100% - **historical-Real9** - finished Jan 2019
[----------] 100% - **historical-Real10** - finished Jan 2019
[----------] 100% - **RCP-2.6-Real1** - started July 19 (see footnote (1))
[----------] 100% - **RCP-2.6-Real2** - DWD - published Dec 2019
[----------] 100% - **RCP-4.5-Real1** - started/finished July 19
[----------] 100% - **RCP-4.5-Real2** - started/finished October 19 - additional realisation due to remaining computing time
[----------] 100% - **RCP-7.0-Real1** - started/finished July 19
[----------] 100% - **RCP-8.5-Real1** - started/finished July 19
[----------] 100% - **RCP-8.5-Real2** - DWD - published Dec 2019
[----------] 100% - **RCP-7.0-Real2** - started/finished July 19
[----------] 100% - **RCP-7.0-Real3** - started/finished July 19
[----------] 100% - **RCP-7.0-Real4** - started/finished July 19
[----------] 100% - **RCP-7.0-Real5** - started/finished July 19
[----------] 100% - **RCP-7.0-Real6** - started/finished July 19
[----------] 100% - **RCP-7.0-Real7** - started/finished July 19
[----------] 100% - **RCP-7.0-Real8** - started/finished July 19
[----------] 100% - **RCP-7.0-Real9** - started/finished July 19
[----------] 100% - **RCP-7.0-Real10** - started/finished July 19

MPI-ESM-1.2-HR CMIP6 FAFMIP simulations

FAFMIP

Type	Experiment	Realization	Ensemble Size	From	Until	Final Date	Comment	Initialization	CMORized	ESGF
faf-heat	faf-heat_r1i1p1f1-HR	1	1	1850	1919	1919	...	cmip6_spinup-HR (2834-12-31)	faf-heat_r1i1p1f1-HR	✅
faf-water	faf-water_r1i1p1f1-HR	1	1	1850	1919	1919	...	cmip6_spinup-HR (2834-12-31)	faf-water_r1i1p1f1-HR	✅
faf-stress	faf-stress_r1i1p1f1-HR	1	1	1850	1919	1919	...	cmip6_spinup-HR (2834-12-31)	faf-stress_r1i1p1f1-HR	✅
faf-all	faf-all_r1i1p1f1-HR	1	1	1850	1919	1919	...	cmip6_spinup-HR (2834-12-31)	faf-all_r1i1p1f1-HR	✅
faf-passiveheat	faf-passiveheat_r1i1p1f1-HR	1	1	1850	1919	1919	...	cmip6_spinup-HR (2834-12-31)	faf-passiveheat_r1i1p1f1-HR	✅
faf-heat-NA50pct	faf-heat-NA50pct_r1i1p1f1-HR	1	1	1850	1919	1919	...	cmip6_spinup-HR (2834-12-31)	faf-heat-NA50pct_r1i1p1f1-HR	✅

MPI-ESM-HR is also used in other MIPs,

FAFMIP (Flux Anomaly Model Intercomparison Project, *Gregory et al., 2016*)

DCPP (Decdal Climate Prediction Projects, *Boer et al., 2016*)

MPI-ESM-1.2-HR CMIP6 DCPP simulations

DCPP

Type	Experiment	Realization	Ensemble Size	From	Until	Final Date	Comment	Initialization	CMORized	ESGF
dcpp-A	"dcpp-A-hindcast.s1960s_r1i1p1f1-HR"	1	10	1960	1970	1970	...	assim-HR	dcppA-hindcast_r1i1p1f1-HR	✅
dcpp-A	"dcpp-A-hindcast.s1960s_r2i1p1f1-HR"	2	10	1960	1970	1970	...	assim-HR	dcppA-hindcast_r2i1p1f1-HR	✅
dcpp-A	"dcpp-A-hindcast.s1960s_r3i1p1f1-HR"	3	10	1960	1970	1970	...	assim-HR	dcppA-hindcast_r3i1p1f1-HR	✅
dcpp-A	"dcpp-A-hindcast.s1960s_r4i1p1f1-HR"	4	10	1960	1970	1970	...	assim-HR	dcppA-hindcast_r4i1p1f1-HR	✅
dcpp-A	"dcpp-A-hindcast.s1960s_r5i1p1f1-HR"	5	10	1960	1970	1970	...	assim-HR	dcppA-hindcast_r5i1p1f1-HR	✅
...										
dcpp-A	"dcpp-A-hindcast.s2018s_r1i1p1f1-HR"	1	10	2018	2028	2028	...	assim-HR	dcppA-hindcast_r1i1p1f1-HR	✅
dcpp-A	"dcpp-A-hindcast.s2018s_r2i1p1f1-HR"	2	10	2018	2028	2028	...	assim-HR	dcppA-hindcast_r2i1p1f1-HR	✅
dcpp-A	"dcpp-A-hindcast.s2018s_r3i1p1f1-HR"	3	10	2018	2028	2028	...	assim-HR	dcppA-hindcast_r3i1p1f1-HR	✅
dcpp-A	"dcpp-A-hindcast.s2018s_r4i1p1f1-HR"	4	10	2018	2028	2028	...	assim-HR	dcppA-hindcast_r4i1p1f1-HR	✅
dcpp-A	"dcpp-A-hindcast.s2018s_r5i1p1f1-HR"	5	10	2018	2028	2028	...	assim-HR	dcppA-hindcast_r5i1p1f1-HR	✅

Type	Experiment	Realization	Ensemble Size	From	Until	Final Date	Comment	Initialization	CMORized	ESGF
dcpp-A	"dcpp-A-hindcast.s1960s_r6i1p1f1-HR"	6	10	1960	1970	1970	...	assim-HR	pending	
dcpp-A	"dcpp-A-hindcast.s1960s_r7i1p1f1-HR"	7	10	1960	1970	1970	...	assim-HR	pending	
dcpp-A	"dcpp-A-hindcast.s1960s_r8i1p1f1-HR"	8	10	1960	1970	1970	...	assim-HR	pending	
dcpp-A	"dcpp-A-hindcast.s1960s_r9i1p1f1-HR"	9	10	1960	1970	1970	...	assim-HR	pending	
dcpp-A	"dcpp-A-hindcast.s1960s_r10i1p1f1-HR"	10	10	1960	1970	1970	...	assim-HR	pending	
...										
dcpp-A	"dcpp-A-hindcast.s2018s_r6i1p1f1-HR"	6	10	2018	2028	2028	...	assim-HR	pending	
dcpp-A	"dcpp-A-hindcast.s2018s_r7i1p1f1-HR"	7	10	2018	2028	2028	...	assim-HR	pending	
dcpp-A	"dcpp-A-hindcast.s2018s_r8i1p1f1-HR"	8	10	2018	2028	2028	...	assim-HR	pending	
dcpp-A	"dcpp-A-hindcast.s2018s_r9i1p1f1-HR"	9	10	2018	2028	2028	...	assim-HR	pending	
dcpp-A	"dcpp-A-hindcast.s2018s_r10i1p1f1-HR"	10	10	2018	2028	2028	...	assim-HR	pending	

MPI-ESM-1.2-LR CMIP6 simulations

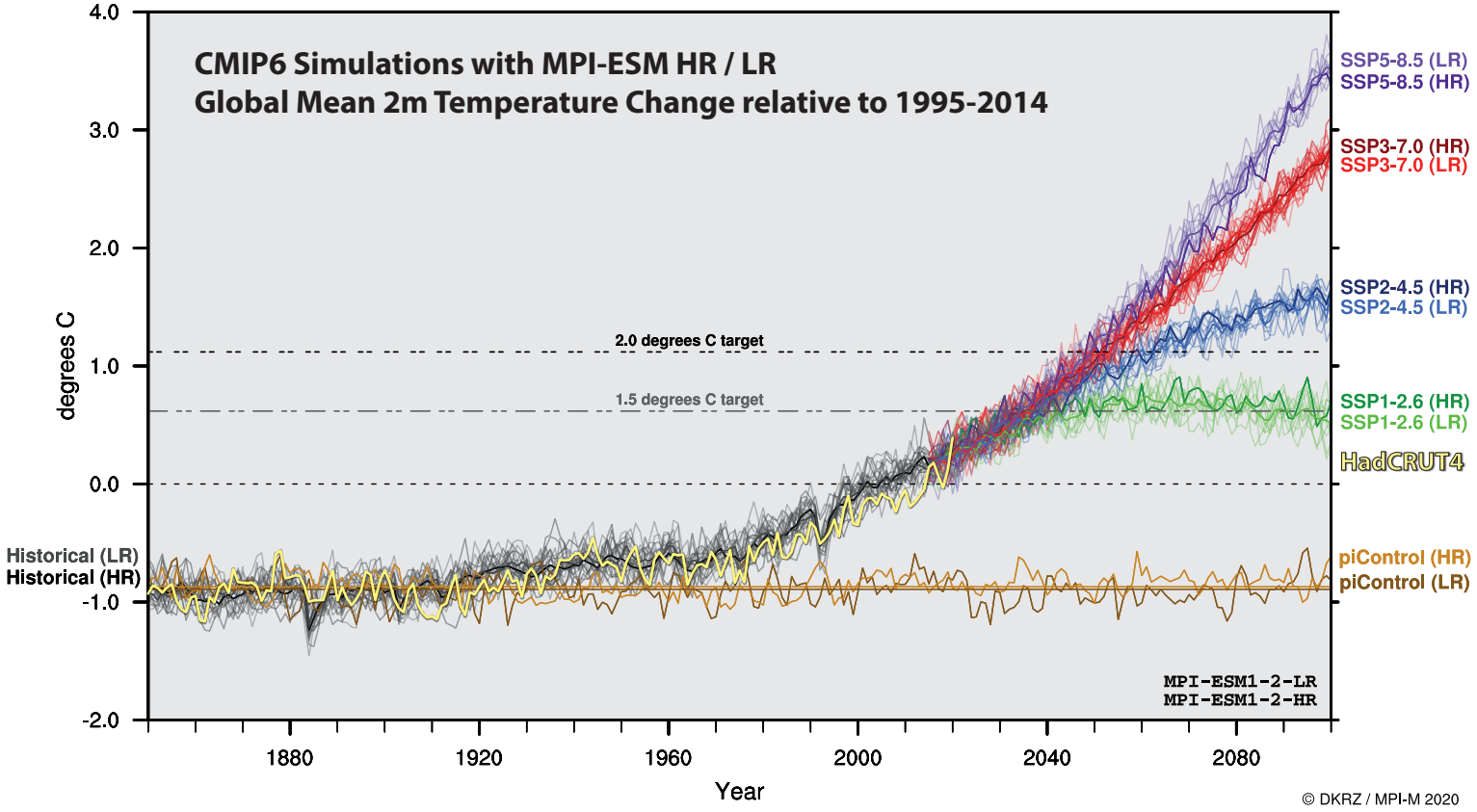
MPI-ESM1.2-LR

DECK

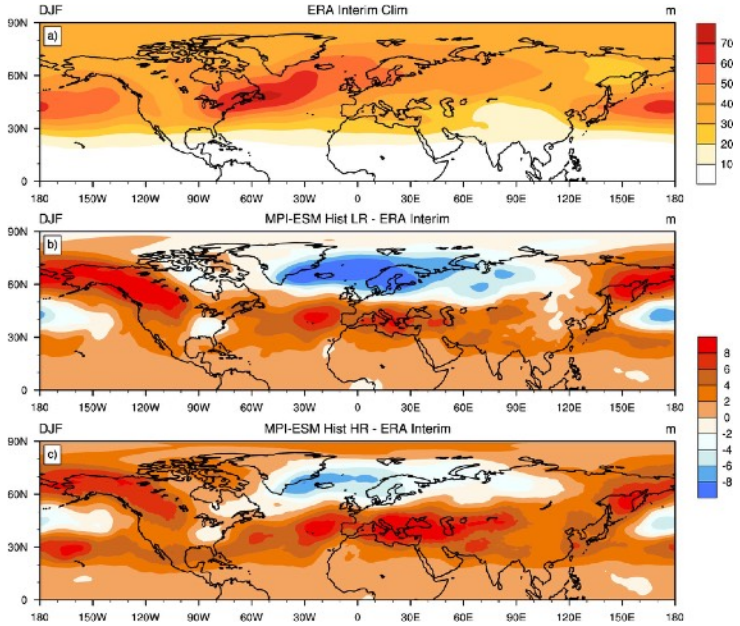
Type	Experiment	Realization	Ensemble Size	From	Until	Final Date	Comment	Initialization	CMORized	ESGF
piControl	khw0096 archive	1	2	1850	2849	2849		vga0218@18991231	piControl_r1i1p1f1-LR	✅
piControl	vga0218	2	2	1900	1999	1999	100 years CMORized; deforest_globe simulations branch from here	vga0218@18991231	piControl_r2i1p1f1-LR	✅
esm-piControl	vga0220	1	1	1850		2965	2250 ff. to be taken as official CMIP control	vga0218@18991231 (echam + oasis), vga0214@36691231 (mpiom)	esm-piControl_r1i1p1f1-LR	✅
1pctCO2	khw0097 archive	1	1	1850	2014	2014		vga0218@18991231	1pctCO2_r1i1p1f1-LR	✅
abrupt-4xCO2	khw0098 archive	1	1	1850	2014	2014		vga0218@18991231	abrupt-4xCO2_r1i1p1f1-LR	✅
amip	khw0109	1	3	1979	2014	2014		mbe1255@197812312		
amip	khw0110	2	3	1979	2014	2014		mbe1255@197812312, enstdif(1979)=1.00001		
amip	khw0111	3	3	1979	2014	2014		mbe1255@197812312, enstdif(1979)=0.99999		

https://code.mpimet.mpg.de/projects/cmip6/wiki/List_of_CMIP6_Experiments

CMIP6 historical and scenario simulations



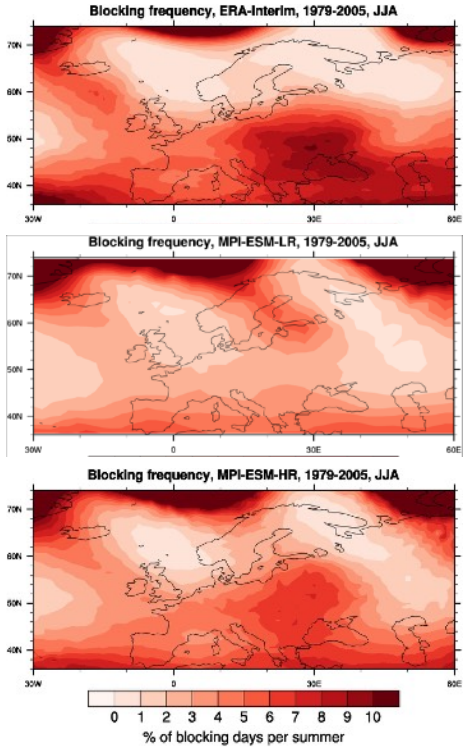
CMIP3/5/6…..HR/LR/XR does it matter?



ERA

LR

HR

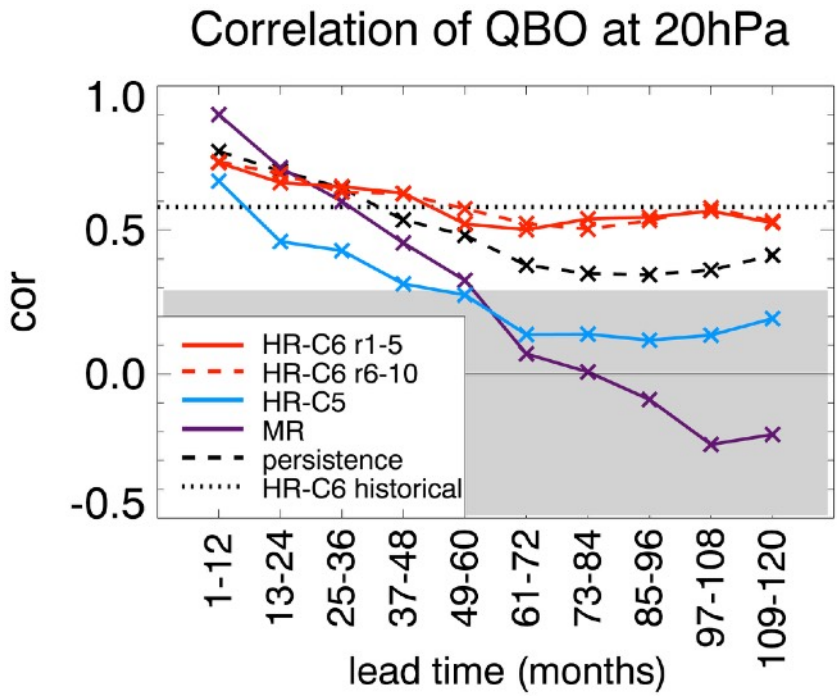


Mueller et al. (2018): improved high-frequency variability and blocking characteristics in HR

Mueller et al., 2018

Improvements related to resolution improve variability characteristics and lead to better forecast skills for extremes over North Atlantic/Europe (Borchert et al., 2019)

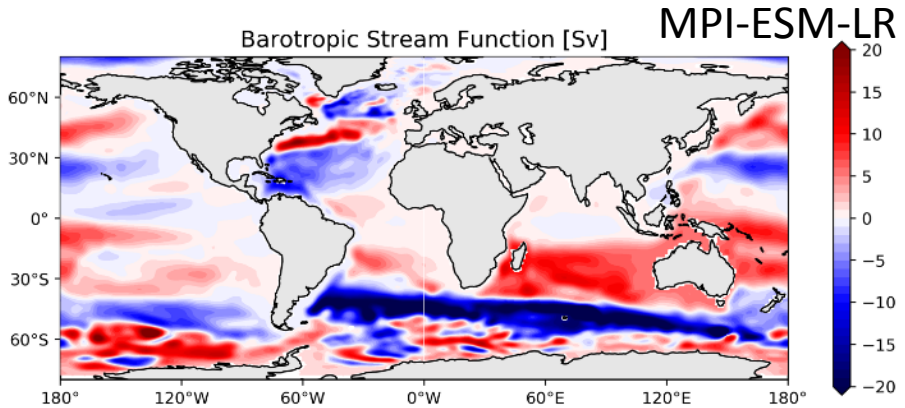
CMIP3/5/6…..HR/LR/XR does it matter?

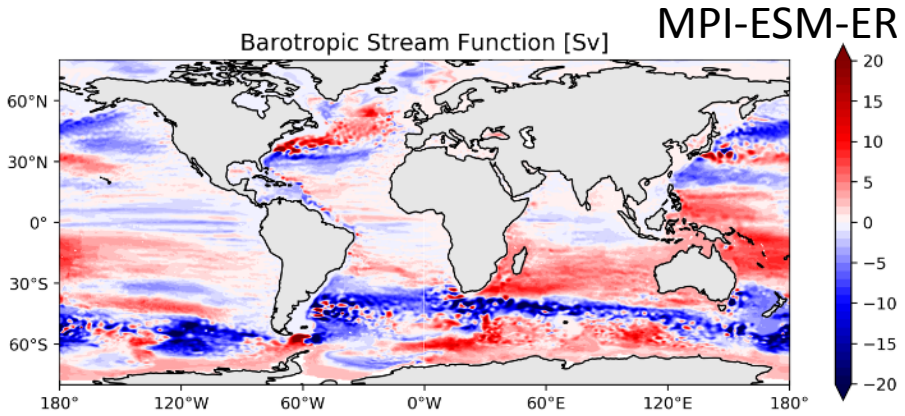


Pohlmann et al., 2019

Predicting the Quasi-Biennial Oscillations requires HR's vertical resolution.
In addition Pohlmann et al. (2019) find that improved CMIP6 external forcing was crucial for realistic hindcasts of the QBO

CMIP3/5/6…..HR/LR/XR does it matter?





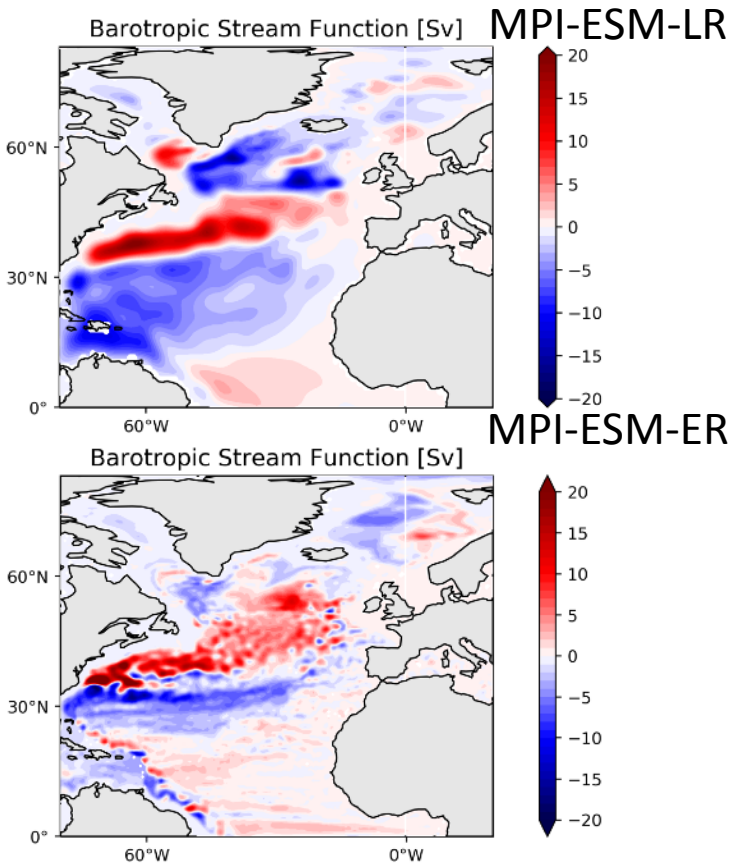
Change in barotropic stream function SSP585 scenario (2095-2100) - (2015-2020)

response in ocean circulation to global warming with typical large-scale structures

differences in magnitude and position of patterns;
some regions, in particular at sub-polar latitudes in NH show different sign

Jungclaus et al., in prep.

Dynamic response to global warming



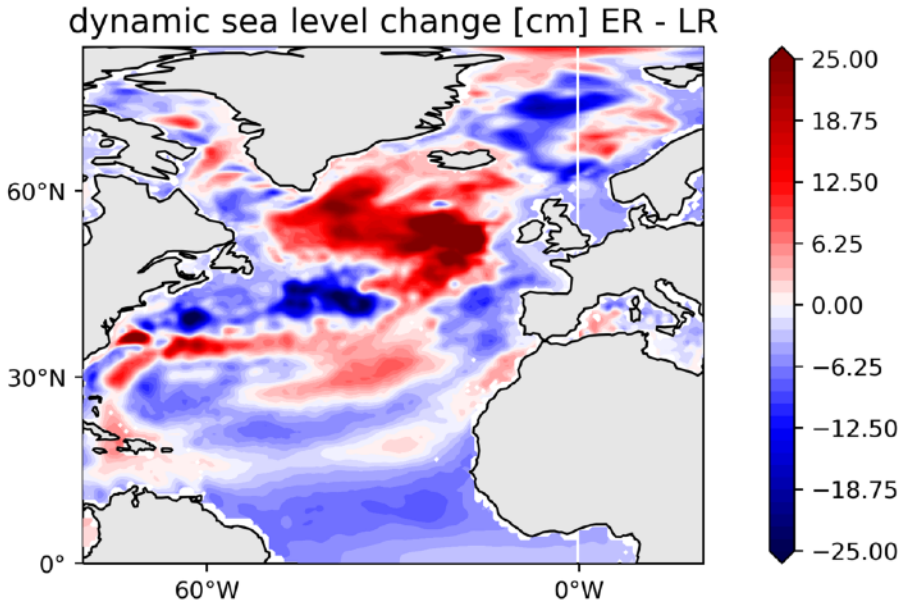
Change in barotropic stream function SSP585 scenario (2095-2100) - (2015-2020)

sub-polar North Atlantic very different with strongly increased cyclonic SPG circulation in “LR”

This has consequences for sea-level change

Different consequences of global warming

Difference in response ER-LR



Regional response to global warming can differ substantially

Sea level change at the end of the 21st century is of high societal relevance

Differences in the responses have similar magnitude as “signal” of global sea level rise

Understanding model differences

FAFMIP with flux forcing derived from CMIP5 1%CO2-increase experiments (Gregory et al., 2016)

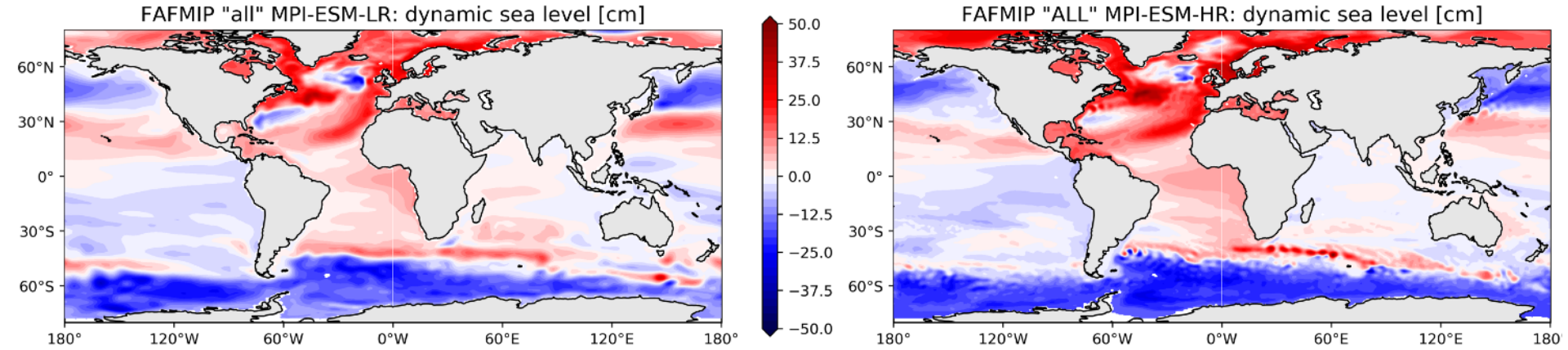
FAFMIP-ALL: all fluxed are applied

FAFMIP-HEAT: only heat fluxes

FAFMIP-WATER: only water

FAFMIP-STRESS: only wind stress

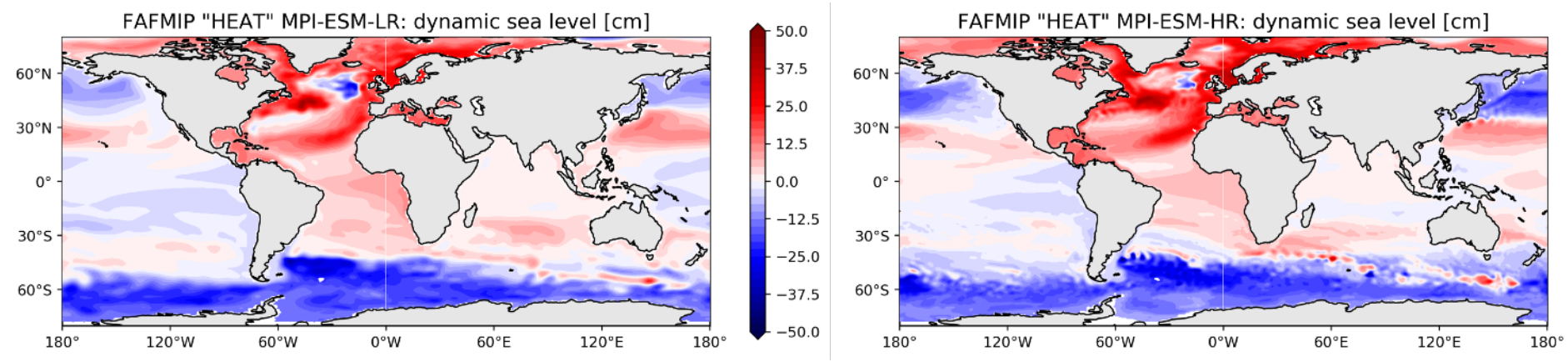
MPI-ESM FAF_ALL



experiments with prescribed fluxes consistent with global warming experiments

stronger negative anomaly in SPG in “LR” also in *FAFMIP-ALL*

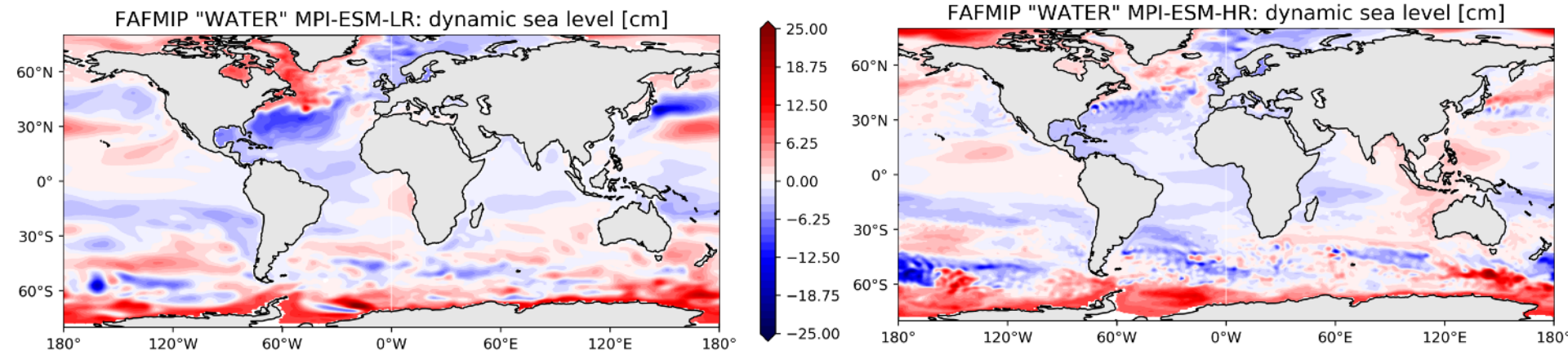
MPI-ESM FAF_HEAT



FAFMIP-HEAT explains most of the changes in the North Atlantic, including SPG

Ongoing analyses focus on deep water mass formation in the North Atlantic

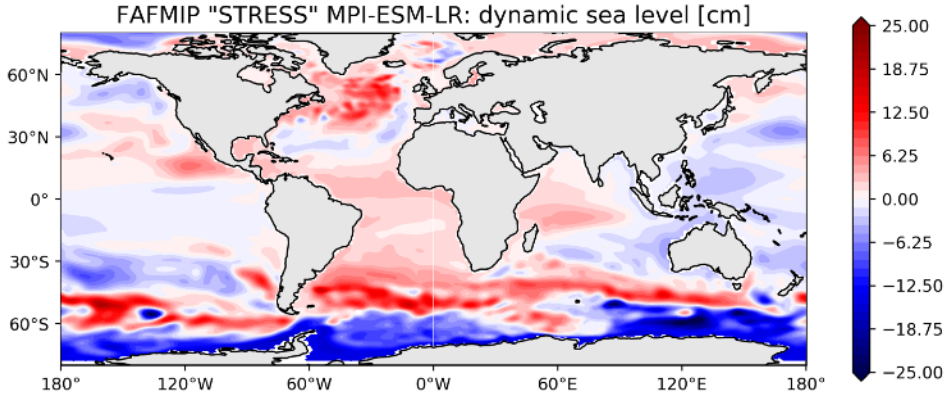
MPI-ESM FAF_WATER

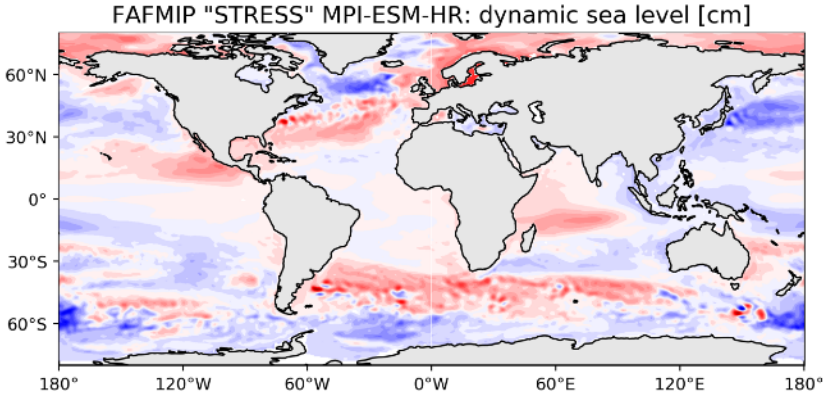


note: colour-scaling changed (50%)

..but also *FAFMIP-WATER* has contributions in the sub-polar oceans (Labrador Sea, sub-tropical Atlantic, NW Pacific), where the response is different in “LR” and “HR”

MPI-ESM FAFMIP experiments



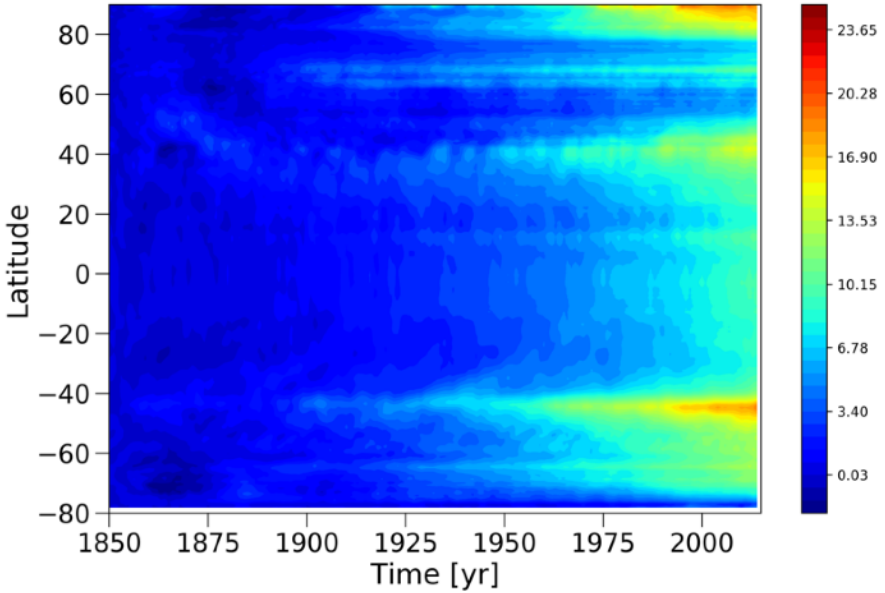


FAFMIP-STRESS features most pronounced changes in Southern Ocean, where resolution plays a large role for ACC position etc.

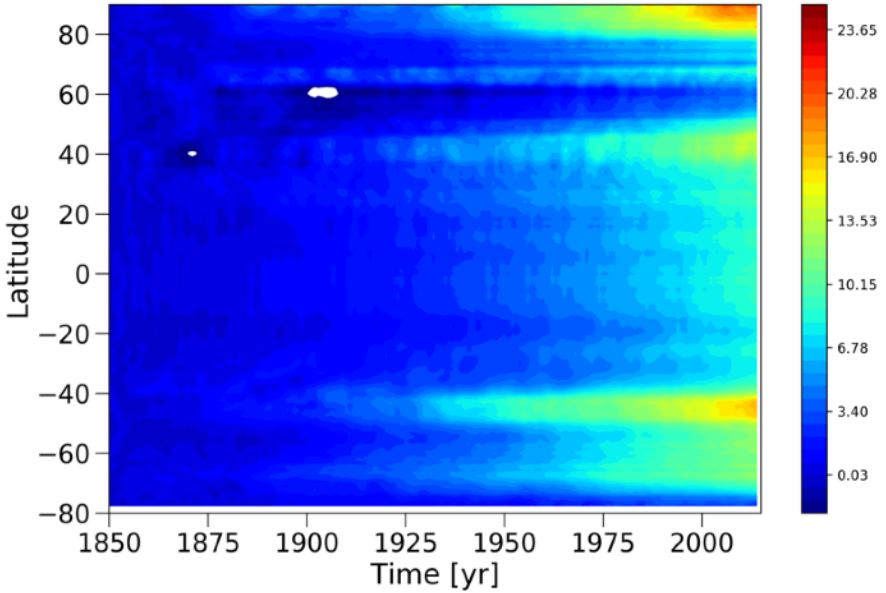
…but also there are differences in the North Atlantic, where wind-stress changes would oppose the negative anomalies seen in “LR” in *FAFMIP-ALL*

Ocean heat uptake in MPI-ESM-LR/HR

MPI-ESM-LR

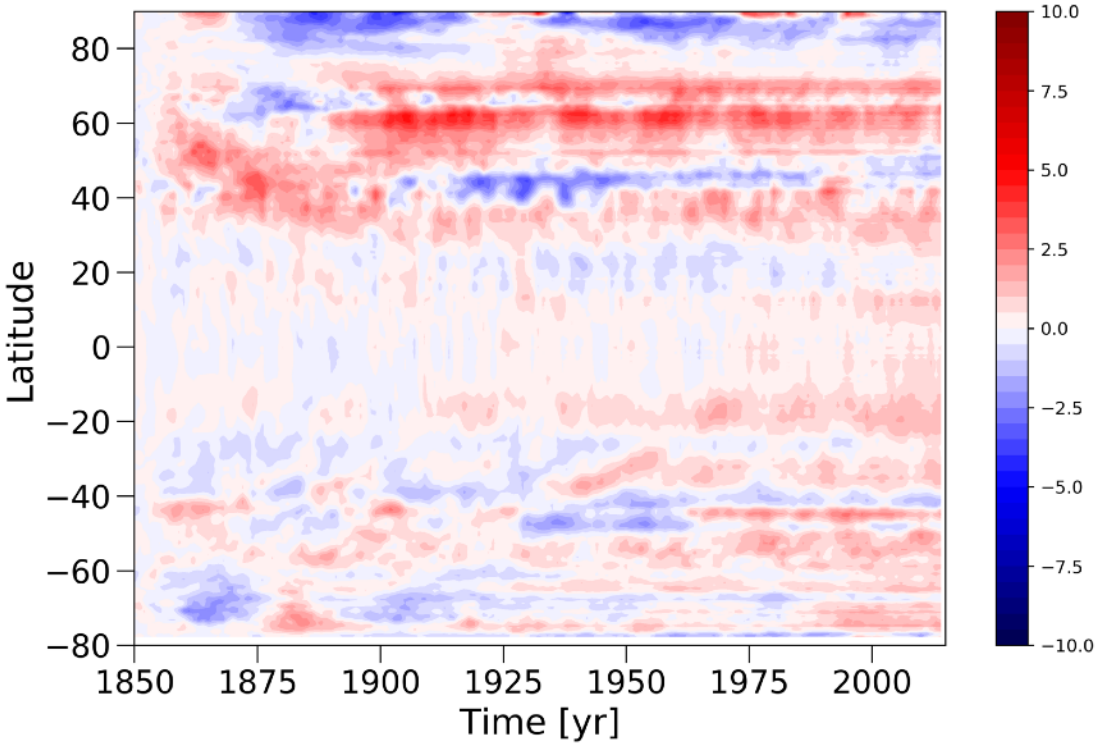


MPI-ESM-HR



Change in zonally-averaged heat content density with respect to 1850-1855

Ocean heat uptake in MPI-ESM-LR/HR



Differences (LR minus HR) in the change in zonally-averaged heat content

first analyses point to differences in sub-polar and higher northern latitudes

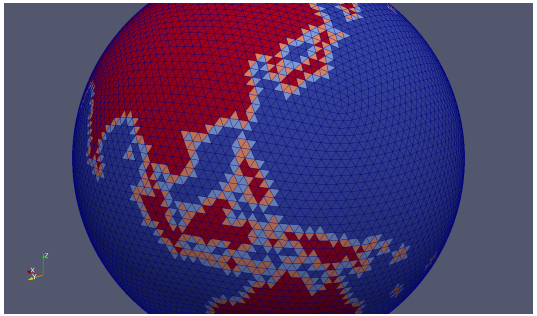
Summary MPI-ESM

- MPI-ESM-HR was successful in providing all planed DICAD experiments
- DICAD provided excellent infrastructure for MPI-ESM
- DICAD-related development were crucial for other versions of MPI-ESM
- Additional MIPs (like FAFMIP) provide additional scientific understanding to evaluate structural uncertainties
- MPI-ESM-LR very efficient tool for long-term integration, large ensembles, and multi-simulation-demanding MIPs

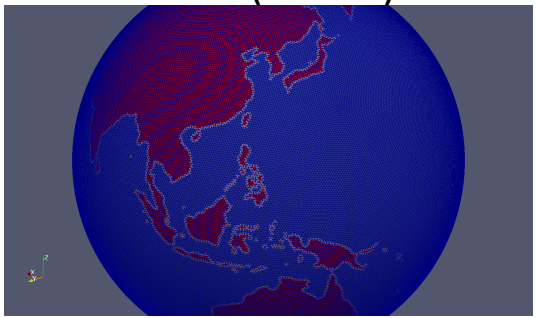
ICON-ESM

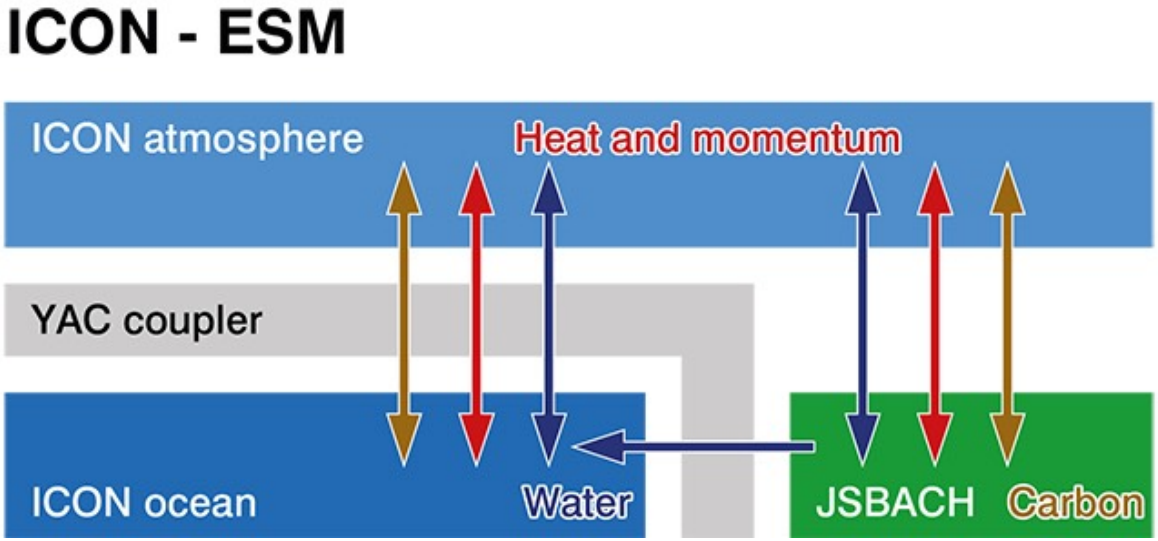
“Ruby-0”

R2B4 (160 km)



R2B6 (40 km)

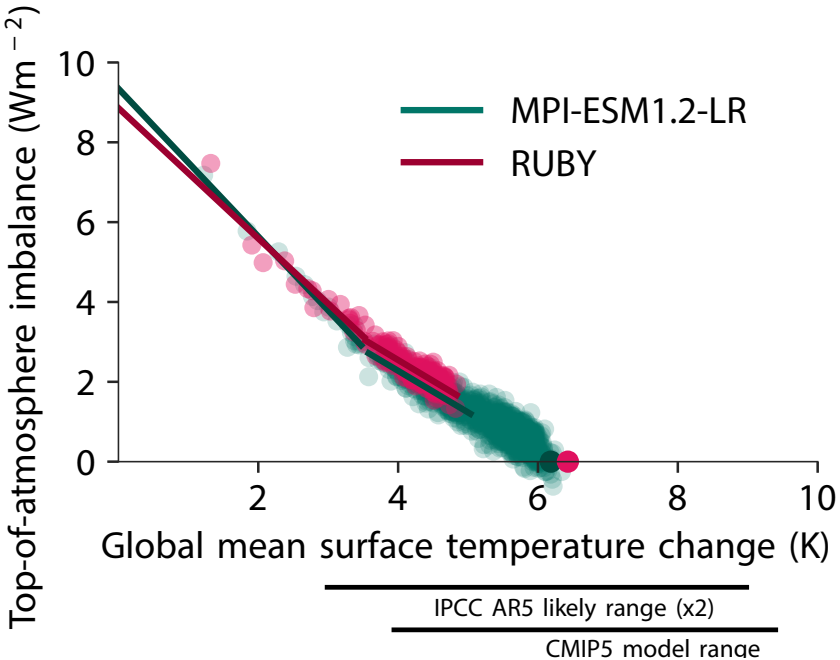




Performance:

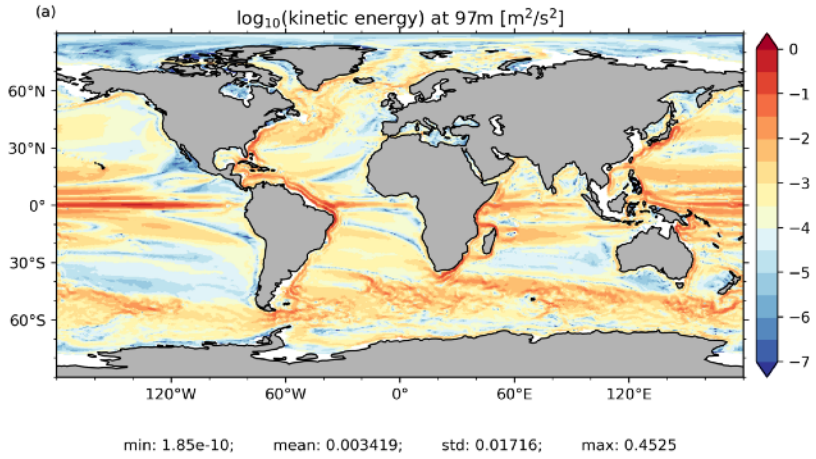
Simulated years per day: 80-100

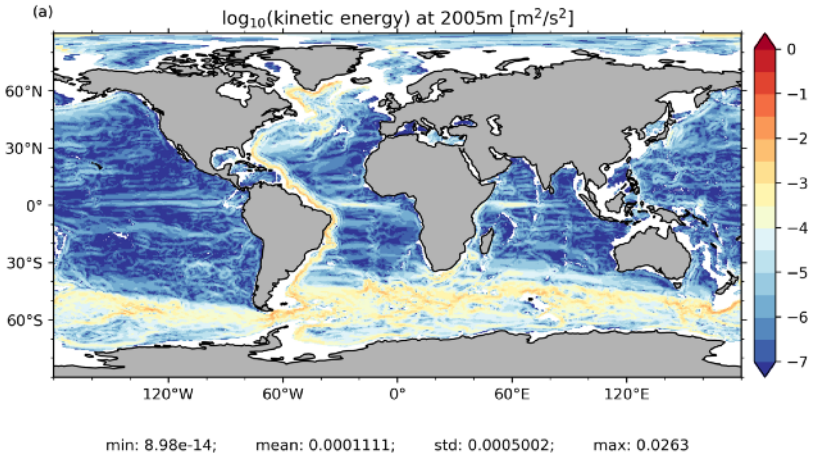
ICON-ESM: Current status



ICON-ESM and MPI-ESM have similar climate sensitivity

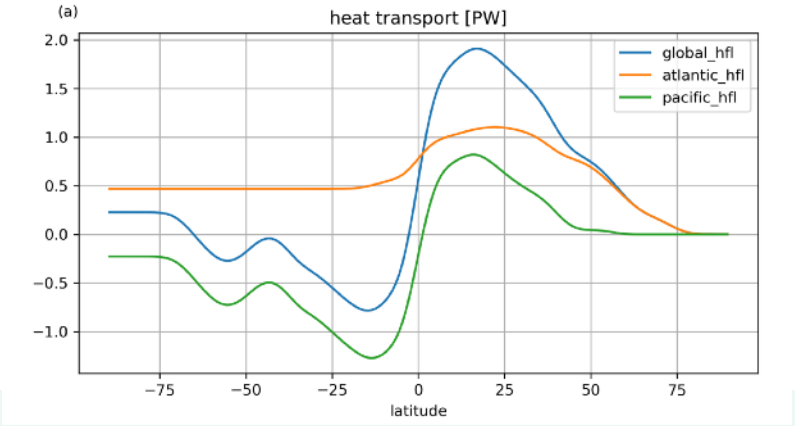
ICON-ESM: Current status





ICON-ESM “Ruby-0” shows good performance in many aspects, but also some remaining deficits

DECK experiments to be carried out 2nd half of 2020

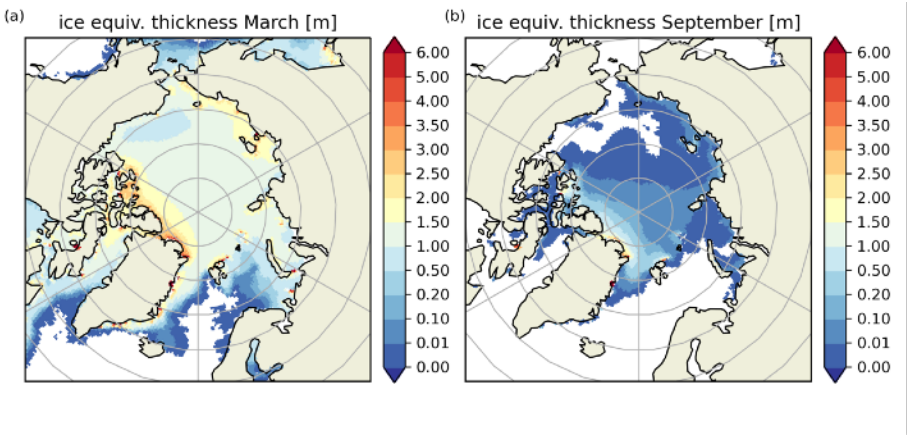


ICON-ESM in DICAD

Tabelle 2a: In diesem DKRZ-Projekt insgesamt geplante CMIP6-Simulationsjahre (2016-2020).

	MPI-ESM1.2.01-HR		ICON-ESM-LR	
	Real.	Jahre	Real.	Jahre
piControl	1	1.000	1	1.000
1ptCO2	1	150	1	150
abrupt4xCO2	1	140	1	140
amip	3	108	1	36
historical	10	1.650	1	165
RCP-2.6	1	86	1	86
RCP-4.5	1	86	1	86
RCP-8.5	1	86	1	86
RCP-7.0	10	860	1	86
Jahre pro Modell		4.166		1.835

DECK experiments to be started August 2020


(a)
ice equiv. thickness March [m]
(b)
ice equiv. thickness September [m]
6.00
5.00
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.20
0.10
0.01
0.00